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INTERNATIONAL COOPERATION IN SEISMOLOGY FOR SUPPORT TO THE CTBT

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ABSTRACT

Regional seismology collaboration efforts in the Middle East have been facilitated by NNSA's Confidence Building Measures Program (CBM) with support from LLNL. The CBM program builds trust, transparency, and capacity among indigenous science and technology communities to address nuclear proliferation and security concerns. This strategic engagement both reduces the danger of nuclear proliferation by engaging local technical experts while laying the groundwork for more formal government-to-government cooperation in potentially sensitive nonproliferation issues. The CBM program promotes seismic monitoring cooperation to raise awareness and understanding of the CTBT and enhance international capabilities to implement the treaty as a means to strengthen U.S. monitoring capabilities. The CBM seismic program focuses on two major directions: Multilateral and bilateral engagement. CBM works bilaterally with countries such as Kuwait, Saudi Arabia, Oman, United Arab Emirates, Jordan and Yemen to improve their seismological expertise and familiarity with the CTBT. In many cases, CBM engagement includes the deployment of seismic stations, joint data analyses and collaborations on technical papers developed for wider peer review in academic communities (Middle East and South Asia). For the multilateral engagement, CBM seismic program participates in other regionally-based projects, including RELSAR (South Asia), RELEMR (Middle East and Mediterranean) and Gulf Seismic Forum (GSF) which are hosted by international partners such as the United Nations Educational, Scientific and Cultural Organization (UNESCO). GSF is a regional seismological meeting organized by hosting institution of Gulf countries. LLNL insures the success of this important meeting in the region of concern. These efforts are to promote the development of a community of local experts capable of working with IDC to address regional verification concerns. CBM partnered with CTBTO to host a workshop is held in Amman-Jordan (September 2010), aimed at enhancing technical engagement with seismology centers throughout the Middle East in turn advancing CTBTO's ratification prospects in the region. The four-day workshop is the first of its kind in the region.

OBJECTIVES

The primary objectives of the Confidence Building Measures (CBM) seismic portfolio are 1) to support the implementation of the Comprehensive Nuclear-Test-Ban Treaty (CTBT), 2) to support US monitoring goals, and 3) to support capacity building in the region. The CBM program aims to build trust, transparency, and capacity among indigenous science and technology communities to address nuclear proliferation and security concerns. These goals are accomplished through a number of coordinated multilateral and bilateral projects.

RESEARCH ACCOMPLISHED

The CBM portfolio accomplishes its mission through a series of meetings including RELEMR, RELSAR, the Gulf Seismic Forum, and CTBTO workshops, as well as a number of bilateral projects. After providing an introduction, we will review many of the individual projects, first with workshops, then with bilateral efforts. Over the past year, we successful conducted the 2010 CTBTO workshop, and have planned for the upcoming 2011 RELEMR workshop in Malta, and the 2012 Gulf Seismic Forum in Jeddah, Saudi Arabia. In addition, continued progress was made on several bilateral projects.

Introduction

LLNL's efforts started as an initiative following the dissolution of the Soviet Union. Various seismological organizations were contacted and research projects supported, primarily in the analysis and interpretation of seismic signals from nuclear explosions in the Soviet Union recorded on internal stations. The US State Department asked DOE if the model of regional engagement through seismology could be applied to the Middle East and in particular, if it could be a possible project in the Arms Control and Regional Security (ACRS) working group of the Middle East Peace Process. A proposal was made and presented by LLNL at the ACRS meeting in 1995, but unfortunately, the Middle East Peace Process was suspended without implementation of the proposal for regional seismic engagement in seismology.

In an effort to maintain the momentum from the ACRS meeting, LLNL joined with the US Geological Survey in supporting the United Nations Educational, Scientific, and Cultural Organization's (UNESCO) Reducing Earthquake Losses in the Extended Mediterranean (RELEMR) program. RELEMR was primarily focused on hazard mitigation and earthquake engineering, and with the addition of LLNL, expanded it scope to include seismology. The primary activity of RELEMR is regional technical meetings and over the years have included most countries in the Middle East and North Africa. Funding of the meetings is primarily from the US State Department and UNESCO.

Parallel to the RELEMR meetings, LLNL initiated a bilateral cooperation with the Jordan Seismological Observatory, which involved a deployment of two broadband seismometers in Jordan, exchange visits of seismologists, and joint research projects. LLNL also initiated a bilateral cooperation with King Saud University in Saudi Arabia which also resulted in temporary deployments of seismic stations as well as an ongoing technical cooperation in seismological research.

In 2001, LLNL, USGS, and UNESCO initiated a new regional cooperation program in South Asia modeling after RELEMR. The program was called Reducing Earthquake Losses in the South Asia Region (RELSAR), and included all South Asian countries as well as China, Iran, and Thailand.

The focus of LLNL's interest in the Middle East changed from the Middle East in general to the Persian/Arabian Gulf region in 2002. Partially as a result of the Masafi earthquakes in the UAE and Oman, LLNL took advantage of the interest in seismology and deployed two temporary broadband seismic stations in the UAE to complement stations already in the region. Also because of the earthquakes and because of concern regarding earthquakes to the economic infrastructure of the region, LLNL and the University of Sharjah initiated a regional seismology meeting and called it the Gulf Seismic Forum (GSF). The first GSF was held in Sharjah, UAE in 2004.

In 2010, in response to the worldwide interest in the CTBT, LLNL worked with CTBTO and initiated the first in an anticipated series of training workshops conducted by LLNL and CTBTO in the CTBT, responsibilities of signatory nations, and in the operation of National Data Centers.

RELEMR workshops

The long-standing RELEMR workshops (Figure 1) have the advantage of including representatives from most seismological organizations in the Middle East and North Africa, including most Arab organizations as well as those from Israel, Turkey, Cyprus, Malta, and Iran. The workshops are held approximately twice a year with funding from the US Department of State, through the US Geological Survey and from UNESCO. Workshop topics have ranged from earthquake engineering, hazard mitigation, and emergency response to regional seismic data analysis, and data sharing. LLNL and the USGS plan and provide the technical content in the meetings.

Figure 1. Data analysis working group at a RELEMR workshop involving researchers from Lebanon, Saudi Arabia, Egypt, Jordan, and Israel.

Workshop venues have been primarily in Turkey and Cyprus in order to allow participants from Israel and the Arab countries to attend and to keep the meetings in the region, however, RELEMR meetings have also been held in Jordan, Egypt, Malta, and several European locations.

RELSAR workshops

The RELSAR workshops are designed similar to RELEMR and include seismological organizations from South Asian countries (India, Pakistan, Nepal, Bhutan, Bangladesh, Sri Lanka), as well as China, and Thailand. Indonesia and Iran have also participated. Seven meetings have been held since the initial meeting in 2001. Venues have included Kathmandu, Nepal, Colombo, Sri Lanka, Dhaka, Bangladesh, Chiang Mai, Thailand, Kunming, China, Xian, China, and Thimphu, Bhutan. Topics have been primarily seismic and included improved event locations along border areas, advanced event processing techniques and identification of active faulting.

The most active participation in RELSAR has been from seismologists in India and Pakistan because of their high level of expertise. Organizations include governmental agencies, national research centers, as well as universities, including representatives from the Pakistan Institute for Nuclear Science and Technology (PINSTECH) as well as the Bhabha Atomic Research Center (BARC) in India participate regularly.

Gulf Seismic Forum

In recognition of the importance of seismology in the Persian/Arabian Gulf region in light of the rapid new construction, and also the multidisciplinary nature of seismology, LLNL and the University of Sharjah planned a Gulf Seismic Forum in 2004. The goals of the GSF were to:

1. To present all relevant research in seismology, earthquake engineering, and hazard mitigation in the region and to make all researchers aware of this work.
2. To advance science and address unique issues for scientists working in the region.
3. To work toward sustainability of the Forum and foster cooperation between organizations and people working in the region.

The GSF successfully accomplished these goals and successive meetings indicate that this interest is increasing judging by the number of papers and the increasing number of organizations which have volunteered to host and sponsor the Forum.

The GSF hosting organization provides all of the funding for the Forum as well as being responsible for the organization. The members of the scientific advisory committee are from organizations in the Gulf region and are responsible for the technical content of the Forum. Representatives from LLNL are on the GSF steering committee as well as the scientific advisory committee.

Figure 2. Opening session of the first Gulf Seismic Forum in 2004, opened by the Crown Prince of Sharjah.

Since the inaugural meeting in 2004 in Sharjah, UAE (Figure 2), the Forum has been held in Al Ain, UAE, Muscat, Oman, Kuwait, Sana'a, Yemen, Abu Dhabi, UAE, and a Forum is planned in 2012 in Jeddah, Saudi Arabia. A permanent organization for the Forum is being formed which would encompass a Gulf Seismological Society as well as a mechanism for future funding.

The Gulf region has recently seen a large growth in the number of structures that could be vulnerable to earthquakes and a resulting increase in the number of seismological and engineering research

organizations, modern seismic networks and seismic network operations. The GSF has proven to be a welcomed means of meeting and exchanging ideas and information about seismology and seismic hazards.

Figure 3. Participants in the workshop hosted by the National Nuclear Security Administration (NNSA) and the Provisional Technical Secretariat (PTS) of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO).

CTBTO workshops

LLNL is working with Comprehensive Test Ban Treaty Organization (CTBTO) in Vienna, Austria in planning a number of training workshops in the Middle East and in south and southeast Asia. An initial capacity building and National Data Center development (NDC) workshop was held in 2010 in Amman, Jordan for MESA countries (Figure 3). At the workshop, representatives from LLNL, NNSA, CTBTO as well as technical experts and government staff from 12 countries worked together to develop a wide-ranging agenda to promote capacity building and transparency, to enhance national capabilities in the implementation of the Treaty, to promote the exchange of experience and expertise among the states in this crucial area of nuclear proliferation. Future workshops are being planned, primarily in regions where LLNL has had extensive technical interactions and experience. These workshops are particularly useful because they focus on issues that are specific to the region which would be useful in implementation of the CTBT monitoring regime.

Bilateral projects

LLNL has deployed temporary seismic instrumentation when programmatic needs indicate that the region would benefit from broadband seismometers. This type of engagement started with the deployment of two broadband stations in Jordan to complement the existing short-period network. Instruments were subsequently deployed in Saudi Arabia and in the UAE to provide data for joint seismic research, regional calibration and noise studies. At present, there is a temporary deployment of stations in Kuwait and a seismic array in Kingdom of Saudi Arabia (KSA) (Figure 4).

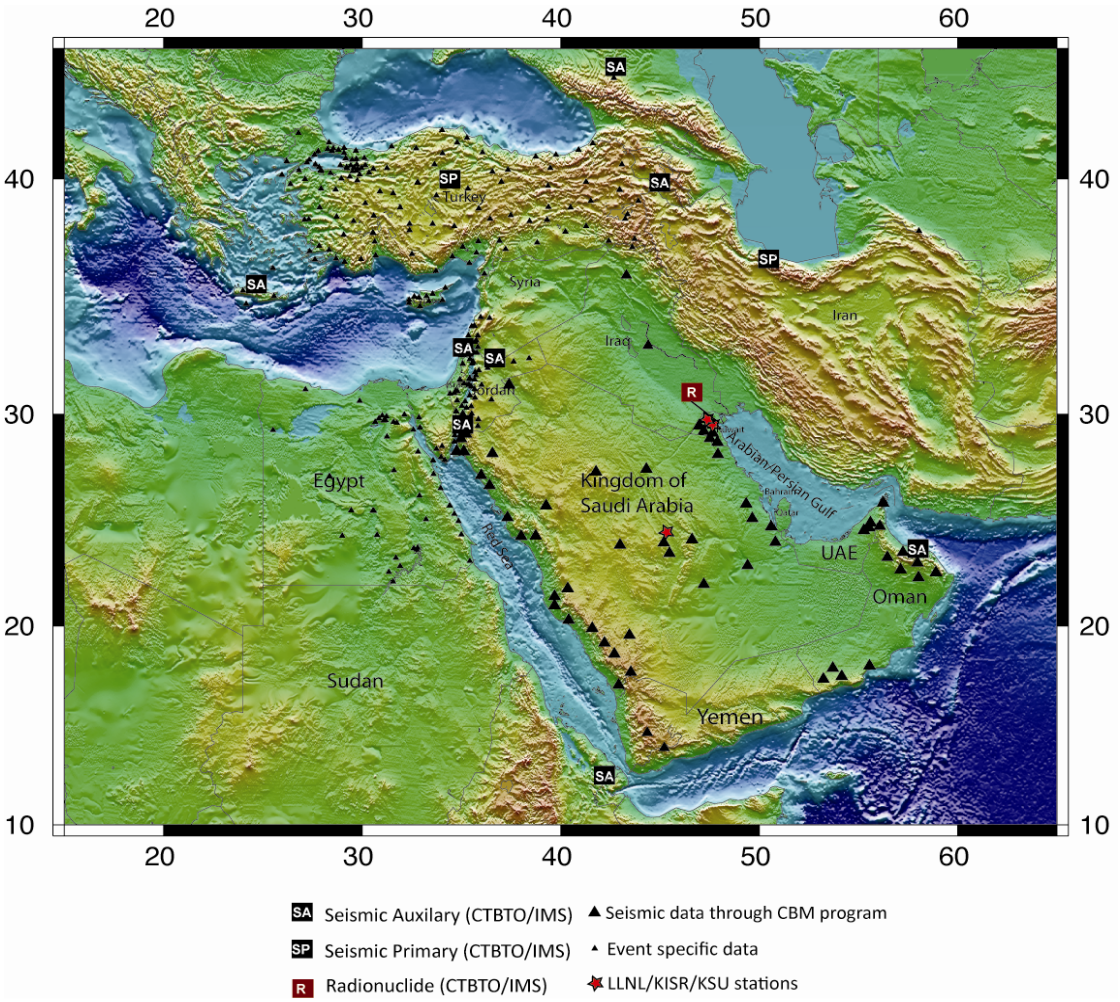

Figure 4. Locations of seismic stations that LLNL obtained seismic data through CBM program. Red starts are stations that are currently in operation (LLNL/MidEast collaborative).

LLNL participates in joint data analysis that would benefit the seismic monitoring capability of a number of countries in the regions, such as Oman, Kuwait, KSA and Iraq. The first attempt to estimate crustal structure by jointly inverting receiver functions with surface waves in Iraq was done in collaboration with experts from the region (Gok et al., 2006).

Kingdom of Saudi Arabia

Since 1999, DOE/NNSA has sponsored an extensive research and engagement between Saudi Arabia and LLNL. This joint work includes data analysis and collaboration and has resulted in number of papers in leading, peer-reviewed seismological journals (e.g. Rodgers et al., 2003; Hansen et al., 2007). A seismic array jointly sponsored with King Saudi University (KSU) is deployed at present (Ar-Rayn) (Figure 5). Ongoing data analysis efforts include a seismic array that was installed in 2010 to improve detection of small events. Initial beam-forming results demonstrate that the array will provide improve estimates of P arrival times and waveforms for small events in the region. We currently have joint seismic data analysis projects with KSU for crustal and upper mantle structure of KSA using broad-band stations and expect additional collaborative efforts in the future. These efforts include assistance from LLNL to the steering committee for the 2012 Gulf Seismic Forum, which will be hosted by the Saudi Geological Survey (SGS) in Jeddah (22-25 January 2012).

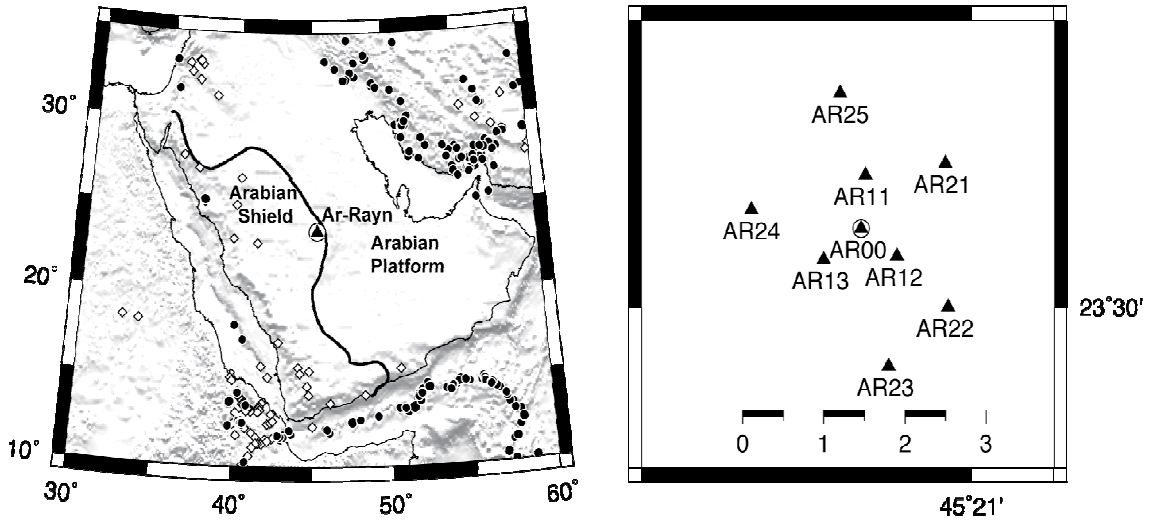

Figure 5 (a) Location map of the Arabian Plate showing major tectonic elements of the Arabian Shield and Platform and the position of the Ar Rayn seismic array (triangle). Earthquakes greater than magnitude 5 for the period 2000-2010 and volcanic centers are indicated by black circles and white diamonds, respectively. (b) The array geometry, which has a broadband sensor (STS-2) at its center (triangle with circle), surrounded by two rings of short-period sensors (triangles).

Kuwait

LLNL collaboration with Kuwait goes back to 1999 when the seismic network of Kuwait was limited and there were problems with network operations. Two peer-reviewed papers were published on the seismic structure and the source characteristics of earthquakes in Kuwait (Pasyanos et al., 2007; Rodgers et al., 2006). Kuwait is a typical example where the CBM program addresses issues related to seismic hazards in the region. Kuwait has concerns about the seismicity and whether they are induced by oil-fields or not and a cooperative project between the Kuwait Institute for Scientific Research (KISR) and LLNL was conducted in May 2010 (Figure 6). Two broadband (BB) three-component stations were deployed in the existing vaults of Kuwait National Seismic Network (KNSN) sites MIB (Mutribah) and UMR (Umm ar Rimam) in order to obtain additional data that would be relevant in addressing this problem.

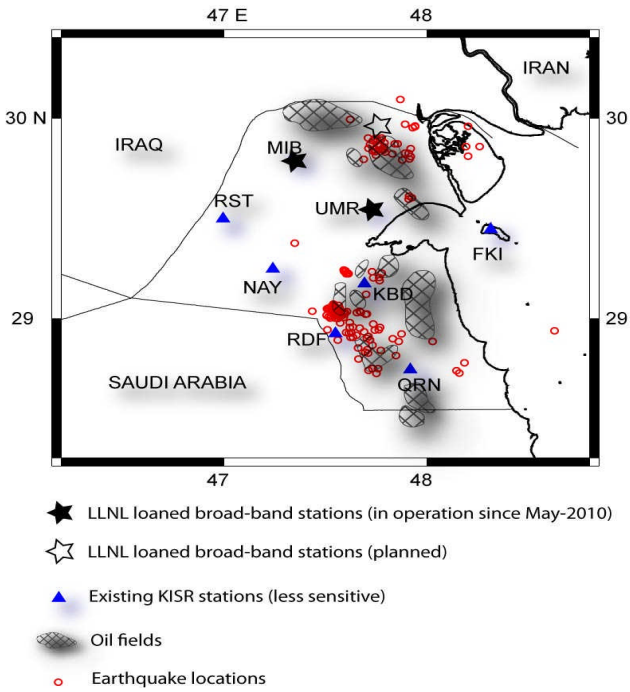

Figure 6. Oil fields and seismicity in Kuwait.

Oman

LLNL collaboration with Oman became very active in 2005. Several projects have started to train Omani seismologists in understanding the structure of Oman and the characteristics of earthquakes within the region. The Oman Earthquake Monitoring Center (EMC), part of Sultan Qaboos University (SQU), operates the national network, which was established in 2004 with 3 broad-band and 10 short period seismic station. LLNL and EMC seismologist published a peer-reviewed article in 2011 (Al-Hashmi et al., 2011), a first attempt to understand the uppermost lithospheric structure in Oman using data from the Oman National Network. Oman is a key partner in the region, due to its location and potential to contribute to seismic monitoring. The Gulf Seismic Forum was hosted and organized by SQU in 2007. LLNL plans to expand and diversify the research and the collaboration with Oman including using data from an IMS auxiliary array in Oman, operated by the EMC.

CONCLUSIONS AND RECOMMENDATIONS

The CBM seismic portfolio is focused on projects that are supportive of CTBT implementation, US monitoring goals, and capacity building in a number of regions. LLNL will focus primarily on the CTBTO workshops in the Middle East and Asia as well as the existing bilateral projects with Kuwait, Oman, and Saudi Arabia. LLNL plans to expand the bilateral projects to UAE and Iraq. The GSF will continue to receive planning assistance and technical guidance, as will RELEMR and RELSAR.

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